

## Here, there and everywhere. Small plastic fragments and pellets on beaches of Fernando de Noronha (Equatorial Western Atlantic)

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Drag your plankton net almost anywhere in the world oceans, or inspect closely any tropical beach and you will find them: virgin plastic pellets and small plastic fragments. What are they, and where do they come from? Virgin plastic pellets are the raw material from which larger molded plastic items are made (Wilber, 1987) and come primarily from plastic industries, flowing into the marine environment by storm-water discharges and direct spills (EPA, 1992). On the other hand, small plastic fragments are the result of successive degradation processes acting on larger plastic debris in the environment (Santos et al., 2009). Reports on the consequences of their presence in the marine environment are alarming (Laist, 1997; Thompson et al., 2004) and evidence strongly suggests that now these marine debris can be found almost anywhere in the oceans (Benton, 1995; McDermid and McMullen, 2004) and coastal environments (Derraik, 2002; Ivar do Sul and Costa, 2007).

We report here the occurrence of virgin plastic pellets and small plastic fragments at the Archipelago of Fernando de Noronha, Equatorial Western Atlantic, a category of plastic debris still normally not considered in the majority of works dealing with marine debris.

Fernando de Noronha Archipelago is formed by the mountain peaks of a volcanic cordillera on the Mid Atlantic Ridge (Fig. 1). The main island has an area of 17 km<sup>2</sup>, and is the only inhabited island, with a population of 2800 residents in 2007 ([www.ibge.gov.br](http://www.ibge.gov.br)). The archipelago is within bounds of two marine/insular conservation units. The majority (70%), including the marine portion (down to 50 m deep), belongs to the National Marine Park of Fernando de Noronha (PARNAMAR). The remaining 30% of the archipelago, which corresponds to the urban areas of the main island, is a Protected Area (APA). At present the majority of the debris found on beaches are from long-distance marine-based sources, as also registered by previous works on oceanic islands (Benton, 1995; Debrot et al., 1999) and pristine continental beaches (Santos et al., 2005). These registers clearly disrespect the Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which prohibits the disposal of plastic debris from ships around the world's oceans.

The archipelago has a tropical climate, with average air temperature around 25° and constant winds predominantly with SE direction. The rainiest period is between February and July (209 mm), while the driest period is between August and January (23 mm). Fernando de Noronha is directly influenced by southeast trade winds and the South Equatorial Current (SEC), but the local circulation patterns remain unknown as no specific works are available. The beaches on the main island are divided in two groups: leeward and windward beaches. The 14 beaches of the leeward side face the continent and have fine sand. The seven beaches of the windward side face the “open ocean”, being subjected to the direct action of waves and winds from the Equatorial Atlantic. These beaches have predominantly medium sand.

A total of 11 beaches were surveyed between March and May 2008, six on the leeward side (Meio, Sancho, Cacimba do Padre,

Boldró, Porto and Bode) and four on the windward side (Atalaia, Sueste, Leão, Caieira and Air France) (Fig. 1). The beaches of Meio, Sueste, Leão and Caieira were surveyed twice. The strandline (1 m wide) was sampled by scraping the two first centimeters of sand from 900 cm<sup>2</sup> quadrats. One to three quadrats were thrown along the strandline on each surveyed beach. Samples were then taken to the laboratory where they were oven-dried at 100 °C overnight. The dry samples were sieved through a 0Φ (1 mm) sieve. The material retained was weighted, examined and classified as plastic fragments, virgin plastic pellets, nylon monofilaments, polystyrene beads, tar and glass. Marine debris were also classified in eight categories according to size: 2–5, <10, <15, <20 mm, which were considered *small* items, and <25, <30, <50, <100 mm, which were considered *medium* size items. The material retained by the sieve was later washed in filtered seawater to further separate the floatable virgin plastic pellets and fragments from the remaining sand. Debris with less than 1 mm were not considered at this stage.

Two-way Analysis of Variance (ANOVA) was made to detect significant differences between windward and leeward beaches, considering both the total number of items and its weight. Statistical significance was set at a probability level of 0.05.

A total of 13,708 g of sand were collected from the eleven beaches surveyed, in a total of 15 quadrats. This sediment contained 329 g (2.4%) of natural organic matter and 26 g of marine debris, which corresponded to almost 0.2% of the total sample. Two hundred and seven debris, were identified in 13 of the 15 sampled quadrats (87%). Eight samples were taken in the five windward beaches. All sampled quadrats were contaminated with 186 items, weighting 24 g, which corresponded to approximately  $4.6 \times 10^{-3}$  g of marine debris in each gram of sand collected. Seven samples were taken in the six leeward beaches. A total of 21 items were collected, which corresponded to  $0.3 \times 10^{-3}$  g of plastics identified in one gram of sand. Two beaches (Bode and Porto) were found not to be contaminated with marine debris during this survey.

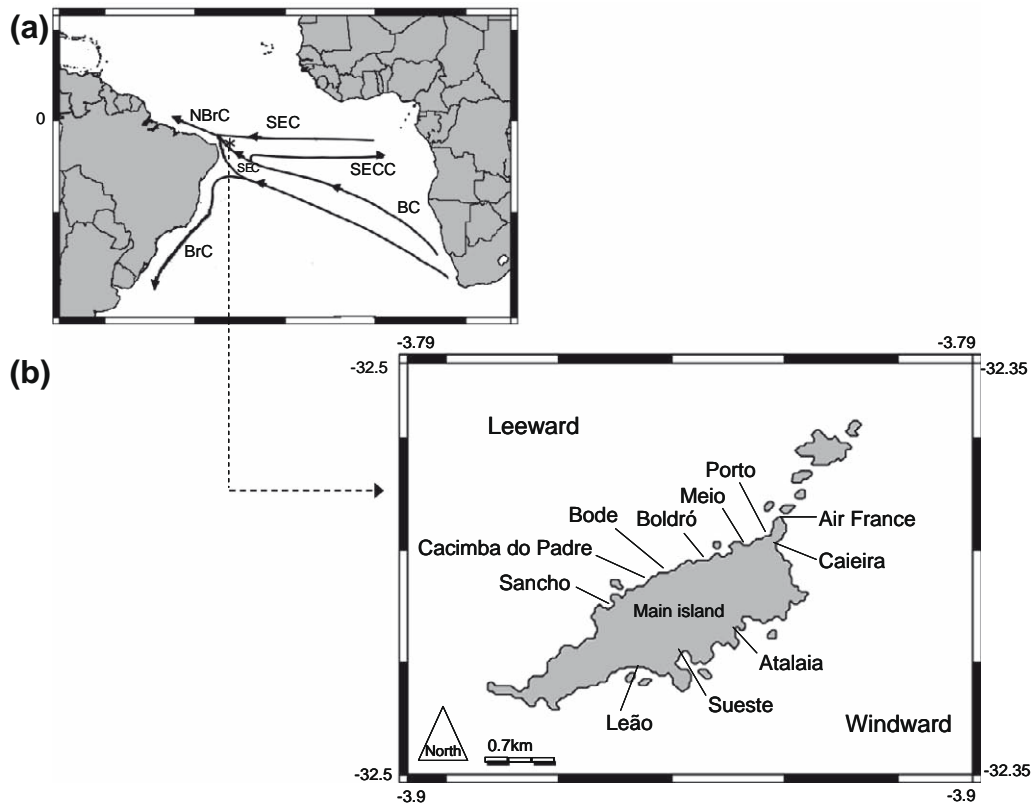
Out of the 207 marine debris identified, 135 were plastic fragments (65%), 48 virgin plastic pellets (23%), 12 glass fragments (6%), 10 nylon monofilaments (5%), one polystyrene bead (0.5%) and one tar residue (0.5%) (Fig. 2). Plastic fragments were sampled in the 13 contaminated quadrats, and were the unique type of item sampled on both sides of the island. Virgin plastic pellets occurred only on the windward side of the island.

Considering size categories of marine debris, 168 items (81%) were classified as small (less than 20 mm) and 39 (19%) were classified as medium (Fig. 3). The smaller sampled size category (2–5 mm) alone accounted for 39% of the items. In this size category are the virgin plastic pellets, which represent 60% of items in the category. Other representative size categories of items were <10 mm (22%) and <15 mm (12%).

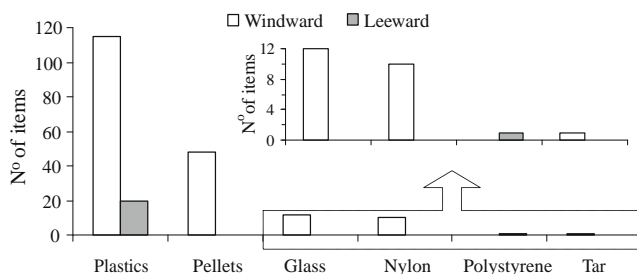
Quantitatively, windward beaches were significantly more contaminated by marine debris than leeward beaches, considering both the total number of items and the total weight of sampled marine debris. For the size categories, no significant difference was detected between windward and leeward beaches, being all size categories equally present on both sides.

Fernando de Noronha Archipelago was mainly contaminated by plastic debris, a word-wide pattern well established in the interna-

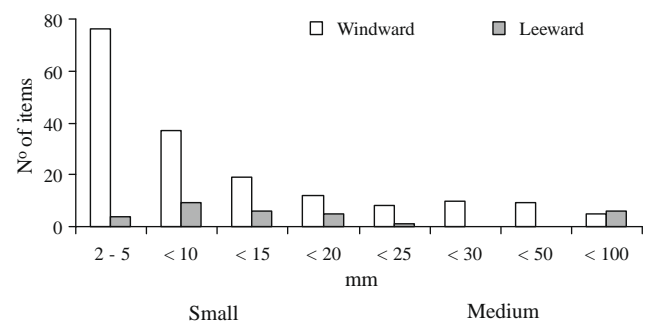
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**Fig. 1.** (a) Position of Fernando de Noronha Archipelago (\*) in the Western Equatorial Atlantic and in relation to the main surface currents (BC = Benguela Current; SEC = South Equatorial Current; SECC = South Equatorial Counter-Current; BrC = Brazil Current; NBrC = North Brazil Current); (b) windward and leeward beaches surveyed at the Fernando de Noronha Archipelago main island.



**Fig. 2.** Total number of marine debris items (2–100 mm) divided according to the different types which occurred on the beaches of the windward and leeward sides of Fernando de Noronha Archipelago between March and May 2008.



**Fig. 3.** Total number of items according to the size categories (small and medium) on beaches of the windward and leeward sides.  $N = 207$ .

tional scientific literature (Derraik, 2002; Ivar do Sul and Costa, 2007). Plastics low density is responsible for the most important environmental consequence regarding this type of marine debris: plastics float, and can be dispersed for long distances, transported as passive tracers, primarily by winds and surface ocean currents (Corbin and Singh, 1993; Kubota, 1994; Kubota et al., 2005).

The South Atlantic Ocean anticlockwise gyre is the major surface sea movement that may transport marine floating debris in the studied region. Fernando de Noronha Archipelago is therefore directly influenced by the SEC, which flows northward to continue as the North Brazil Current. As registered, windward beaches had greater amounts of marine debris than leeward beaches, which confirmed the influence of surface currents transporting floating marine debris, a pattern also noted on previous works (Debrot et al., 1999). The contamination by virgin plastic pellets on Fernando de Noronha windward beaches is also a very strong signal of the influence of surface currents in transporting marine debris.

As there is no plastic industry on the island, and the port facilities are used for small boats and cargo items only, these pellets certainly come from the sea, floating on its surface and moved by winds and superficial currents.

In addition, two other hypotheses are possible. First, large items are being transported by currents and winds, and once deposited on the beaches of Fernando de Noronha, suffer continued fragmentation. Second, the fragments themselves are being transported by currents, and finally deposited on the beaches. Long-term monitoring of windward and leeward beaches, as well as specific fragmenting process experiments are necessary to clarify this and other questions.

Two major consequences of these size categories of marine debris to the Fernando de Noronha biota can be suggested. First, all monitored marine debris had <100 mm and are available to be ingested by seabirds, turtles, fishes and mammals. Secondly, marine-

based sources of plastics will almost certainly implicate in the occurrence of fouling items on beaches and adjacent seas. Regions of high endemism, as Fernando de Noronha, are probably those most at risk of invasive species (Barnes and Fraser, 2003).

This work reinforces the idea of the prevalence of virgin plastic pellets and plastic fragments as a world-wide marine contaminant. At present they represent one of the most important plastic contaminants at the Fernando de Noronha Archipelago Marine National Park and adjacent Conservation Unit.

The fact that the majority of marine debris found in Fernando de Noronha comes from ocean sources shows the high vulnerability of this archipelago and its organisms to marine pollution. Virgin plastic pellets and small plastic fragments are beyond any sort of existing (or economically viable) cleaning technology. Therefore, to prevent the contamination of remote environments, it is urgent that international agreements, such as the Annex V of the MARPOL, are completely put into practice and obeyed by all parties and stakeholders. Furthermore, managerial actions and public participation in pollution prevention on the island will be absolutely crucial to avoid the generation of autochthonous plastic debris which may develop into small fragments.

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## Persistent organochlorine pollutants in Korean offshore waters: Squid (*Todarodes pacificus*) as a biomonitor

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### ABSTRACT

Persistent organochlorine pollutants (POPs) such as polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethane and its metabolites (DDTs), chlordane compounds (CHLs), and hexachlorocyclohexanes (HCHs) were determined in Japanese common squid collected from the offshore waters of Korea. Liver accumulated higher levels of contaminants than mantle. The sums of DDTs, PCBs, CHLs and HCHs in liver were in the ranges of 164–4430 ng g<sup>-1</sup>, 95–1030 ng g<sup>-1</sup>, 15–121 ng g<sup>-1</sup>, and 13–98 ng g<sup>-1</sup> on a lipid weight basis, respectively. Among the POPs, DDTs showed distinct regional difference in concentration levels and composition between the western and eastern offshore of Korea. One of the highest concentrations of DDTs so far recorded in the western offshore of Korea, that is Yellow Sea. This implies ongoing fresh input of technical DDT to this regional sea. HCHs were relatively high in the Yellow Sea as well, with an enhanced signal of  $\gamma$ -HCH indicating recent input of lindane. In contrast, CHLs showed higher level in the eastern offshore of Korea, that is East Sea, but PCBs showed an even distribution in both regions. Squid could be a useful bio-indicator for monitoring offshore water contamination by POPs.

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In order to evaluate the contamination of persistent organochlorine pollutants (POPs) in Korean coastal areas, many studies have been conducted in near shore water, sediment, and biota